CLAIMS

We claim:

1. A method for quality control testing of a laser shock peening process of production workpieces, the method comprising the following steps:

(a) laser shock peening surface of the production workpiece by firing a plurality of laser beam pulses from a laser shock peening system on the surface of the production workpiece and forming a plurality of corresponding plasmas, each one of the plasmas for each one of the pulses having a duration in which the plasma causes a region to form beneath the surface, the region having deep compressive residual stresses imparted by the laser shock peening process,

(b) measuring at least one natural frequency for each of the laser beam pulses during a period of time during the duration of each corresponding one of the plasmas,

(c) calculating natural frequency shifts from a baseline natural frequency for the measured natural frequencies for at least a portion of the laser beam pulses, and

(d) using the natural frequency shifts for accepting or rejecting the workpiece with respect to pass or fail criteria for quality assurance of the laser shock peening process.

2. A method as claimed in claim 1 wherein the pass or fail criteria is based on a pre-determined natural frequency shift correlation based on measured test piece natural frequencies and high cycle fatigue failure from high cycle fatigue tests of test pieces that were laser shock peened in the same or similar laser shock peening apparatus.

3. A method as claimed in claim 2 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test piece that was laser shock peened in the same or similar laser shock peening apparatus.

4. A method as claimed in claim 1 wherein the measuring is performed using a contact vibration sensor connected to the workpiece.

5. A method as claimed in claim 4 wherein the pass or fail criteria is based on a pre-determined natural frequency shift correlation based on measured test piece natural frequencies and high cycle fatigue failure from high cycle fatigue tests of test pieces that were laser shock peened in the same or similar laser shock peening apparatus.

6. A method as claimed in claim 5 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test piece that was laser shock peened in the same or similar laser shock peening apparatus.

7. A method as claimed in claim 4 wherein the vibration sensor is mounted on the workpiece.

8. A method as claimed in claim 7 wherein the pass or fail criteria is based on a pre-determined natural frequency shift correlation based on measured test piece natural frequencies and high cycle fatigue failure from high cycle fatigue tests of test pieces that were laser shock peened in the same or similar laser shock peening apparatus.

9. A method as claimed in claim 7 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test

piece that was laser shock peened in the same or similar laser shock peening apparatus.

10. A method as claimed in claim 1 wherein the measuring is performed using a microphone spaced away from the workpiece.

11. A method as claimed in claim 10 wherein the pass or fail criteria is based on a pre-determined natural frequency shift correlation based on measured test piece natural frequencies and high cycle fatigue failure from high cycle fatigue tests of test pieces that were laser shock peened in the same or similar laser shock peening apparatus.

12. A method as claimed in claim 11 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test piece that was laser shock peened in the same or similar laser shock peening apparatus.

13. A method as claimed in claim 1 wherein the measuring is performed using a non-contact laser gage.

14. A method as claimed in claim 13 wherein the pass or fail criteria is based on a pre-determined natural frequency shift correlation based on measured test piece natural frequencies and high cycle fatigue failure from high cycle fatigue tests of test pieces that were laser shock peened in the same or similar laser shock peening apparatus.

15. A method as claimed in claim 14 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test piece that was laser shock peened in the same or similar laser shock peening apparatus.

16. A method as claimed in claim 1 wherein the natural frequency shifts are differences between the measured natural frequencies for at least a portion of the laser beam pulses and the baseline natural frequency.

17. A method as claimed in claim 16 wherein the baseline natural frequency is one of the measured natural frequencies.

18. A method as claimed in claim 16 wherein the baseline natural frequency is a first one of the measured natural frequencies.

19. A method as claimed in claim 16 wherein the baseline natural frequency is a measured natural frequency of a non-laser shock peened test piece.

20. A method as claimed in claim 19 wherein the non-laser shock peened test piece is the workpiece before it is laser shock peened.

21. A method as claimed in claim 16 wherein each of the test pieces included a failure precipitating flaw within a laser shock peened area of the test piece that was laser shock peened in the same or similar laser shock peening apparatus.

22. A method for quality control testing of a laser shock peening process of production workpieces, the method comprising the following steps:

(a) laser shock peening surface of the production workpiece by firing a plurality of laser beam pulses from a laser shock peening system on the surface of the production workpiece and forming a plurality of corresponding plasmas, each one of the plasmas for each one of the pulses having a duration

in which the plasma causes a region to form beneath the surface, the region having deep compressive residual stresses imparted by the laser shock peening process,

(b) measuring at least one natural frequency for each of the laser beam pulses during a period of time during the duration of each corresponding one of the plasmas,

(c) calculating natural frequency shifts from a baseline natural frequency for the measured natural frequencies for the measured natural frequencies for at least a portion of the laser beam pulses,

(d) calculating a statistical function value of the workpiece based on the natural frequency shifts, and

(e) comparing the statistical function value to a pass or fail criteria for quality assurance of the laser shock peening process for accepting or rejecting the workpiece.

23. A method as claimed in claim 22 wherein the statistical function values are calculated using a statistical function chosen from of a group of statistical functions consisting of an average of at least a portion of the natural frequency shifts, a standard deviation of at least a portion of the natural frequency shifts, and a trend of at least a portion of the natural frequency shifts.

24. A method as claimed in claim 23 wherein the natural frequency shifts are differences between the measured natural frequencies for at least a portion of the laser beam pulses and the baseline natural frequency.

25. A method as claimed in claim 24 wherein the baseline natural frequency is one of the measured natural frequencies.

26. A method as claimed in claim 24 wherein the baseline natural frequency is a first one of the measured natural frequencies.

27. A method as claimed in claim 24 wherein the baseline natural frequency is a measured natural frequency of a non-laser shock peened workpiece.

28. A method as claimed in claim 22 wherein the measuring is performed using a contact vibration sensor connected to the workpiece.

29. A method as claimed in claim 28 wherein the vibration sensor is mounted on the workpiece.

30. A method as claimed in claim 22 wherein the measuring is performed using a microphone spaced away from the workpiece.

31. A method as claimed in claim 22 wherein the measuring is performed using a non-contact laser gage spaced away from the workpiece.